Unraveling Genetic Processes in Arid Soils Using Micromorphology

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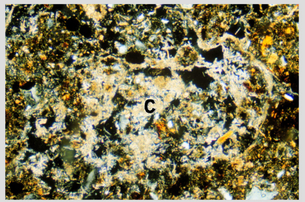
Introduction

Micromorphology is useful in visualizing and comprehending soil genetic processes that occur in arid environments. Desert soils, typically Aridisols or Entisols (Soil Survey Staff, 1999), have weathering and depositional products (i.e., minerals) which are quite visible in thin sections of soil fabric. Lack of sustained moisture defines the taxonomic concept of Aridisols and results in the accumulation of secondary minerals such as calcite, silica, and gypsum. Shape and color are two properties used to identify minerals in soil fabric. Through identification and arrangement of these minerals in soil fabric, we can better understand chemistry and genetic processes of the soil. The objective of this presentation is to illustrate common features in soil fabrics of arid environments and describe soil processes that are responsible for their formation and arrangement. We will initially examine isolated examples of several constituents: carbonates, silica, gypsum, and aluminosilicate clay. Subsequently, we will feature examples of these minerals co-existing in soil fabrics and briefly discuss pedo- and polygenetic implications of fabric arrangements.

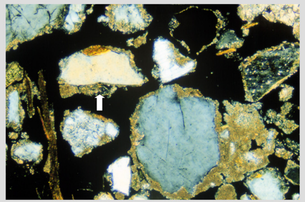
Abbreviations Used

PPL = Plain Polarized Light
XPL = Crossed Polarized Light
C = Carbonate
O = Opal
CH = Chalcedony
V = Void
QZ = Quartz
A = Argillan
FD = Feldspar

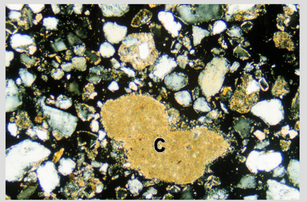
Carbonate Accumulation



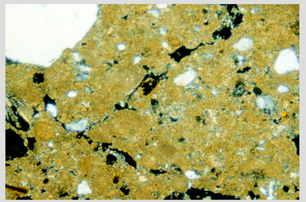
Soil Name: Not Designated (SSL 87P220)
Horizon: 3Bk (53-100 cm)
Location: Yemen
Feature: Carbonate needles (XPL)
Comment: This horizon was described in the field as having carbonates present as filaments and as coatings on pebble bottoms. The horizon has 3% $CaCO_3$. This degree of deposition represents an early stage (Stage I of four stages) of carbonate accumulation (Gile and Grossman, 1979).



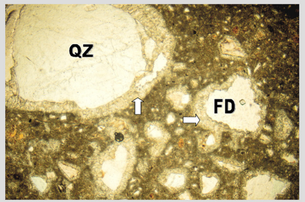
Soil Name: Cax (SSL 97P420)
Horizon: Bkg2 (54-69 cm)
Location: San Bernardino Co., CA
Feature: $CaCO_3$ around sand grains in a coarse-textured matrix (XPL)
Comment: Referred to as calcitans (Brewer, 1976), their formation illustrates attraction to and deposition of carbonates on mineral surfaces (e.g., quartz, feldspars) accessible to percolating water. This morphological form (continuous grain coatings) represents an early to middle stage (Stage II) of carbonate deposition.



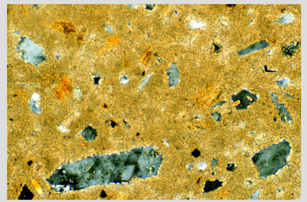
Soil Name: Ulando (SSL 97P465)
Horizon: Bw3
Location: Sante Fe Co., NM
Feature: Carbonate segregation (XPL)
Comment: A carbonate segregation is present in the lower center of the photomicrograph. Segregations or masses represent a Stage II accumulation in which grain surfaces are generally coated and carbonate masses are beginning to form in intergranular spaces. This horizon has 7% $CaCO_3$.



Soil Name: Major (SSL 95P609)
Horizon: Bkyc (18-56 cm)
Location: Cochise Co., AZ
Feature: Matrix of soil fabric is nearly filled or plugged with carbonates (XPL)
Comment: Voids, as channels and pores, are still evident. Horizon has 60% $CaCO_3$. This represents Stage III carbonate accumulation.

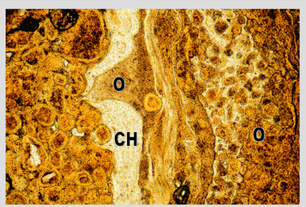


Soil Name: Libby (SSL 95P608)
Horizon: 2Btkyc2 (65-150 cm)
Location: Cochise Co., AZ
Feature: Coarse crystalline carbonates (arrows) around sand grains embedded in a fine-grained carbonate matrix (PPL)
Comment: Differences in crystal sizes reflect differential rates of formation suggesting two sequences of carbonate accumulation. Horizon has 71% $CaCO_3$ and represents Stage III accumulation.

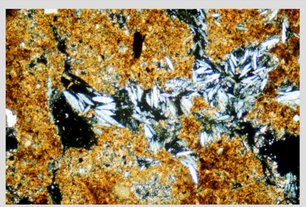


Soil Name: La Palma (SSL 71C022)
Horizon: Ckm (68-73 cm)
Location: Maricopa Co., AZ
Feature: Petrocalcic horizon (XPL)
Comment: Horizon is engulfed by carbonates (79% $CaCO_3$) in which crystals are interlocked or cemented. The section shown is Stage III carbonate accumulation. Pedogenic carbonates are generally silt-sized crystals (visible here) versus carbonates inherited from parent materials which are typically sand-sized (Doner and Lynn, 1989).

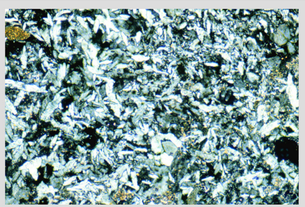
Silica & Gypsum Accumulation



Soil Name: Not Designated (SSL 87P513)
Horizon: 2Bkqm
Location: Jefferson Co., OR
Feature: Duripan with silica cementation (PPL)
Comment: Fabric has an opal and chalcedony laminar cap. The matrix above and below is composed of durinodes (non-crystalline silica) surrounded by moderately-oriented silicate clays. Clay can provide the initial absorption surface for silica in soil solution. The absorption of silica onto established silica phases leads to formation of nodules (Bottinger and Southard, 1990). Carbonate is absent in this horizon.

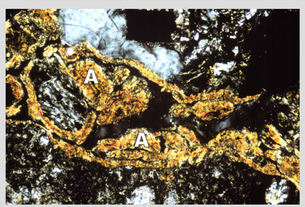


Soil Name: Prelo (SSL 74C027)
Horizon: Cky (82-114 cm)
Location: Otero Co., NM
Feature: Gypsum crystals in void (XPL)
Comment: Pedogenetic gypsum has a characteristic lenticular shape. Soil matrix surrounding void is composed of carbonate and silicate clays. Horizon has 24% gypsum and 21% $CaCO_3$. Gypsum often forms near the base of the wetting front in arid soils (Nettleton et. al., 1982).

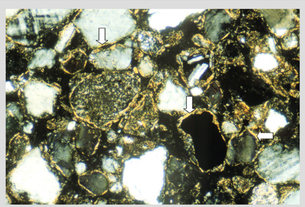


Soil Name: Not Designated (SSL 74C029)
Horizon: Bym (48-66 cm)
Location: Otero Co., NM
Feature: Petrogypsic horizon (XPL)
Comment: Gypsum is the predominant constituent in this horizon (89%). Induration occurs via desiccation and interlocking of crystals. Carbonates composed 10% of the horizon, though typically gypsum segregates from silicate clays and carbonates (Allen, 1985). Small masses of carbonates are scattered throughout the photomicrograph.

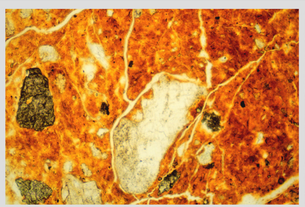
Clay Accumulation



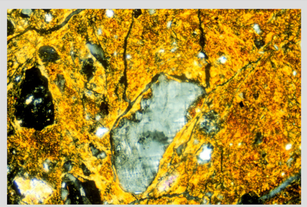
Soil Name: Harqua (SSL 71C003)
Horizon: Btk3 (58-84 cm)
Location: Maricopa Co., AZ
Feature: Argillan (XPL)
Comment: Clay films in this photomicrograph have coarse lamination and moderate orientation. Argillans formed as a result of desiccation. The laminar bodies appear to be detaching, a sign of degradation. Clay eluviation is a common feature in arid region soils. Their presence is generally tied to late-Pleistocene and older surfaces (Gile and Grossman, 1968).



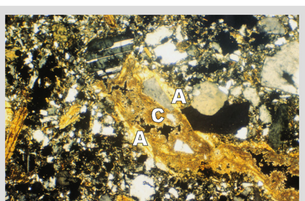
Soil Name: Clovis (SSL 40A711)
Horizon: Bt1 (8-20 cm)
Location: Apache Co., AZ
Feature: Free grain argillans (XPL)
Comment: Clay is often associated with sand grain surfaces (arrows) in horizons with low quantities of clay (11.6% in this horizon). Clay orientation results from normal packing of loose grains in sandy soils (Brewer, 1976).



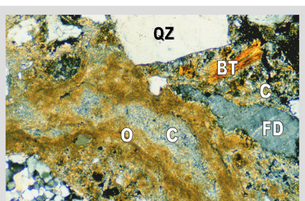
Soil Name: White House (SSL 40A001)
Horizon: BCtk (79-97 cm)
Location: Cochise Co., AZ
Feature: Oriented plasma fabric (PPL, XPL)
Comment: Horizons with high percentages (57.4% in this horizon) of expandable aluminosilicate clay-sized minerals become aligned through shrink-swell processes. This alignment results in preferred orientation of clay particles, making the plasma anisotropic (visible under cross-polarized light). This process results in loss of argillans in many soils.



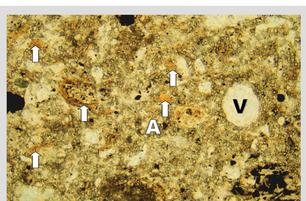
Interrelationship of Constituents



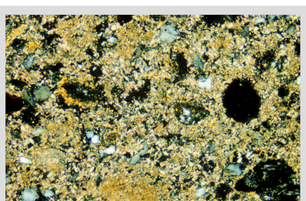
Soil Name: Jerryslu (SSL 93P245)
Horizon: Btkqm2 (107-126 cm)
Location: Tulare Co., CA
Feature: Channel lined with oriented clay, silica, and carbonates (XPL)
Comment: Determining the sequence of pedogenic processes is an important use of micromorphology. Photomicrographs illustrate multiple processes during pedogenesis. Clay is initially deposited in the channel as a moderately oriented argillan (yellow). Secondarily, laminar silica is deposited along the channel. Finally, carbonate nearly fills the remaining pore space. Crystals of carbonate are evident along the edge of the remaining void.

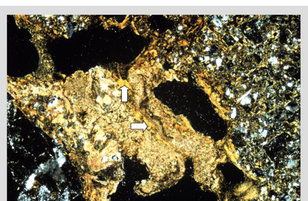


Soil Name: Welport (SSL 98P298)
Horizon: A/Bkqm (26-40 cm)
Location: Kern Co., CA
Feature: Pore lined with silica and carbonates (XPL)
Comment: Small amounts of somewhat laminar opal silica initially line the pore, followed by carbonates. These two components are generally found as discrete entities (Boettinger and Southard, 1990). Silica typically is absorbed to surfaces and intermixes with clays and sesquioxides in the soil matrix, while carbonates tend to precipitate in homogeneous deposits in voids (Chadwick, et al., 1987; Singh and Gilkes, 1993). Note the partially weathered biotite and the plagioclase feldspar exhibiting albite twinning.

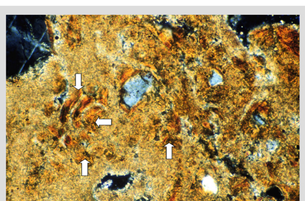


Soil Name: Harqua (SSL 71C003)
Horizon: Btk1 (13-31 cm)
Location: Maricopa Co., AZ
Feature: Argillans distrupted by carbonates and salts (PPL, XPL)
Comment: Fragments of argillans (arrows) are scattered through the matrix of carbonate crystals. Argillans, formed earlier in the genesis of this soil, are later disrupted by the infusion of salts and carbonates (24% in this horizon). (Compare with photo of argillans from the Btk3 horizon of the same pedon. Argillans remain intact in the lower horizon.) Note the vesicle (circular void), which forms through the entrapment of gas in salt-affected surface horizons. Both salts and carbonates increase below the desert pavement in this pedon to a shallow depth (<50 cm). This fact suggests that these constituents are translocating through the pedon and accumulating at the depth of wetting. Electrical conductivity (EC) of the soil solution is sufficiently high to maintain flocculation of clays, but argillans are disrupted in the high salt horizons. The occurrence of argillans below the depth of present-day wetting (see photo of the Btk3 horizon above) suggests that at this location the present arid environment was preceded by a more moist one.

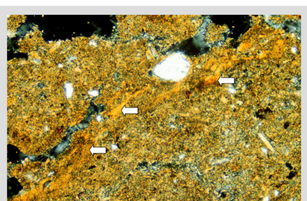




Soil Name: Cristobal (SSL 81P370)
Horizon: Bt1 (3-8 cm)
Location: Mohave Co., AZ
Feature: Argillans distrupted by salts and carbonates (XPL)
Comment: The void is bridged by multiple argillan fragments (arrows) sandwiched between carbonates and salts. Clay in argillans is poorly oriented as a result of disruption.



Soil Name: Ligurta (SSL 40A677)
Horizon: Bt (3-8 cm)
Location: Yuma Co., AZ
Feature: Packets of clay (arrows) are randomly distributed through a silty matrix (XPL)
Comment: The EC in this horizon is 30 dS cm^{-2} and is likely higher in undersaturated conditions. This EC is sufficient to maintain flocculation of clay, which is translocated as a unit (Nettleton, et al., 1990).



Soil Name: Gadson (SSL 81P384)
Horizon: A3 (10-23 cm)
Location: Yuma Co., AZ
Feature: Buried surficial crusts (XPL)
Comment: Young alluvial soil with seasonal deposition. 11% carbonates, 1.2% salts, and exchangeable Na greater than 50%. Clay is flocculated by the high salt concentration. Crusts (arrows) form on surface of soil upon drying. The crust has a similar appearance of an argillan, but has poor orientation and no lamination.

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